Strong correlation between superconductivity and pressure-induced ferromagnetic fluctuations in UGe_2

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The coexistence of superconductivity and ferromagnetism carried by the same electrons was thought to be a fantastic theoretical possibility after its prediction by Ginzburg[1]. Recently, the discovery of the superconductivity in uranium ferromagnets UGe_2[2], URhGe[3], and UCoGe[4] has attracted much attention since the same 5*f* electrons of uranium atoms are responsible for the two states. As unconventional superconductivity has been typically found around the boundaries of magnetic ordered phases in strongly correlated electron systems, it is important to study a relation between the magnetism and the superconductivity. Neutron scattering studies have shown correlations between the superconductivity and magnetic excitations in high-T_c cuprate, iron arsenide, and heavy fermion superconductors. Here, we report a clear correlation between the superconductivity and pressure-induced ferromagnetic fluctuations in UGe_2.

Figure 1 shows the temperature-pressure phase diagram in UGe_2[5]. Open circles and closed triangles represent the Curie temperature T_{Curie} determined by the resistivity and present magnetic measurements. T_{Curie} decreases with increasing pressure from 53 K at ambient pressure. The ferromagnetic state disappears above P_c ~ 1.5 GPa. There is an additional boundary T_x that splits the ferromagnetic phase into FM2 and FM1. Open and closed diamonds represent T_x determined by the resistivity and the magnetic measurements. The critical pressure of T_x is P_x ~ 1.2 GPa. The superconductivity (SC) appears from approximately 1.0 GPa to P_c. The superconducting transition temperature T_{sc} becomes highest near the phase boundary of FM1 and FM2 at P_x. The microscopic origin of the transition from FM2 to FM1 has not been understood yet. The spontaneous magnetic moment p_s, the coefficient of the T^2-term in the resistivity A and the linear specific heat coefficient γ show drastic changes at P_x[2].

We measured dc magnetization at high pressure in UGe_2 with a miniature ceramic-anvil high-pressure cell (mCAC) designed by us for use in a commercial SQUID magnetometer[6]. A high-quality single crystal of UGe_2 with residual resistivity ratio *RRR* = 600 was used. The magnetic data were analyzed using Takahashi's spin fluctuation theory[7]. We determined the pressure dependencies of the widths of the spin fluctuation spectrum T_0 and T_A in the energy and momentum spaces, respectively.

Figure 2(a) shows the pressure dependencies of T_0 and T_A. Both quantities show anomalous enhancements from 1.0 to P_c where the superconductivity appears. This suggests the change of the spin fluctuation spectrum. The pressure dependence of T_0 can be expressed as $T_0(P) = T^*_0 + \Delta T_0(P)$ where $T^*_0 = 95$ K is a pressure-independent constant. Figure 2(b) shows the pressure dependencies of $\Delta T_0(P)$ (right axis) and T_{sc} determined by the resistivity measurement (left axis). The pressure dependence of $\Delta T_0(P)$ scales with that of $T_{sc}(P)$. This suggests a clear correlation between the superconductivity and pressure-induced ferromagnetic fluctuations with characteristic energy of 300 K developing around P_x, the phase boundary of FM1 and FM2. Theoretically, it has been suggested that the *p*-wave ferromagnetic superconductivity is mediated by critical ferromagnetic fluctuations around a ferromagnetic quantum critical point[8]. Meanwhile, this study suggests the importance of the phase boundary of FM1 and FM2 for the superconductivity in UGe_2.

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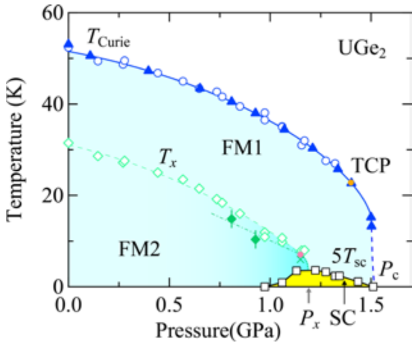

Fig. 1 Temperature-pressure phase diagram in UGe_2[5].

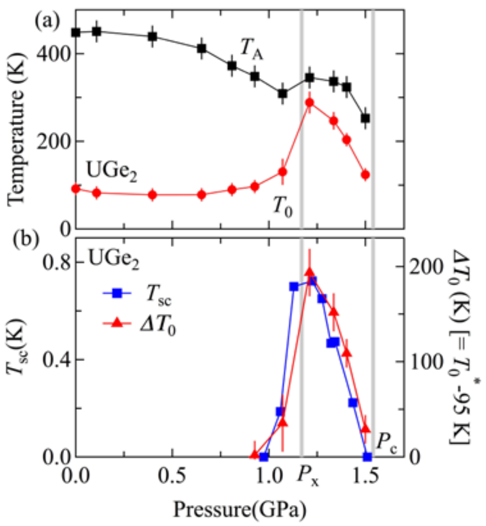

Fig. 2 Pressure dependencies of (a) the widths of the spin fluctuation spectrum T_0 and T_A, and (b) T_{sc} (left axis) and $\Delta T_0(P)$ [$=T_0(P)$-95 K] (right axis) in UGe_2[5].

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